



Buildroot: what's new?

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Corrections, suggestions, contributions and translations are welcome!





- ▶ CTO and Embedded Linux engineer at ~~Free~~ **Electrons** → **Bootlin**
 - ▶ Embedded Linux specialists.
 - ▶ Development, consulting and training.
 - ▶ <https://bootlin.com>
- ▶ Contributions
 - ▶ **Kernel support for the Marvell Armada** ARM SoCs from Marvell
 - ▶ Major contributor to **Buildroot**, an open-source, simple and fast embedded Linux build system
- ▶ **Toulouse**, south west of France
- ▶ Windsurfing, snowboarding





Poll time

- ▶ Who already knows about Buildroot ?



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- ▶ Who is already using Buildroot ?



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- ▶ Who is already using Buildroot ?
- ▶ Who is using OpenEmbedded / Yocto Project ?
- ▶ Who is using OpenWRT / LEDE ?
- ▶ Who is using another build system ?



Buildroot at a glance

- ▶ Is an **embedded Linux build system**, builds from source:
 - ▶ cross-compilation toolchain
 - ▶ root filesystem with many libraries/applications, cross-built
 - ▶ kernel and bootloader images
- ▶ **Fast**, simple root filesystem in minutes
- ▶ **Easy** to use and understand: kconfig and make
- ▶ **Small** root filesystem, default 2 MB
- ▶ More than **2300 packages** available
- ▶ Generates filesystem images, not a distribution
- ▶ Vendor neutral
- ▶ Active community, stable releases every 3 months
- ▶ Started in 2001, oldest still maintained build system
- ▶ <http://buildroot.org>



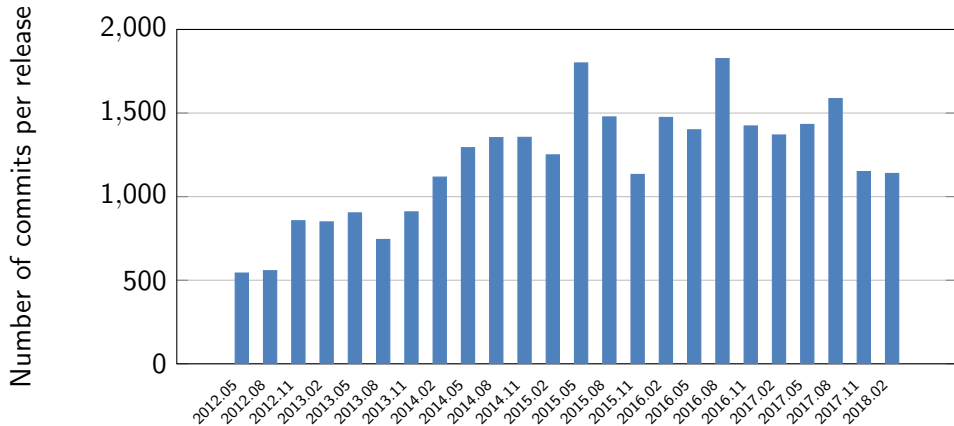


What's new?

- ▶ Last *What's new* talk at the *Embedded Linux Conference 2014*, i.e 4 years ago
- ▶ Lots of things have changed and improved in Buildroot since then, time for a new *What's new* talk!
- ▶ Main topics discussed
 - ▶ Project activity
 - ▶ Release schedule and LTS
 - ▶ Architecture support
 - ▶ Toolchain support
 - ▶ Infrastructure improvements
 - ▶ Testing improvements
 - ▶ Misc



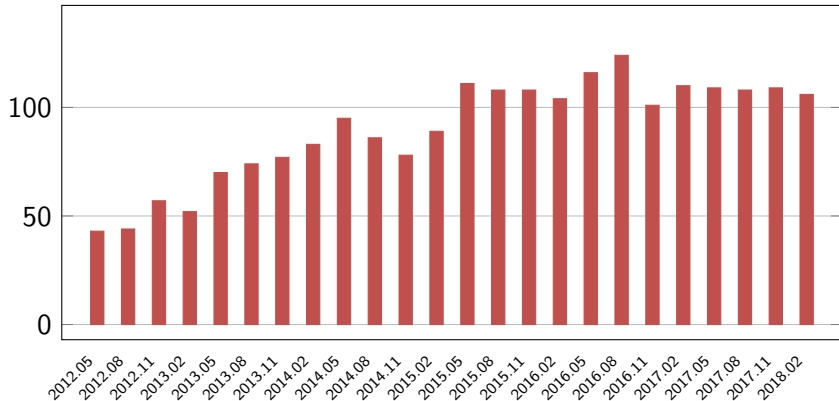
Project activity: per commits





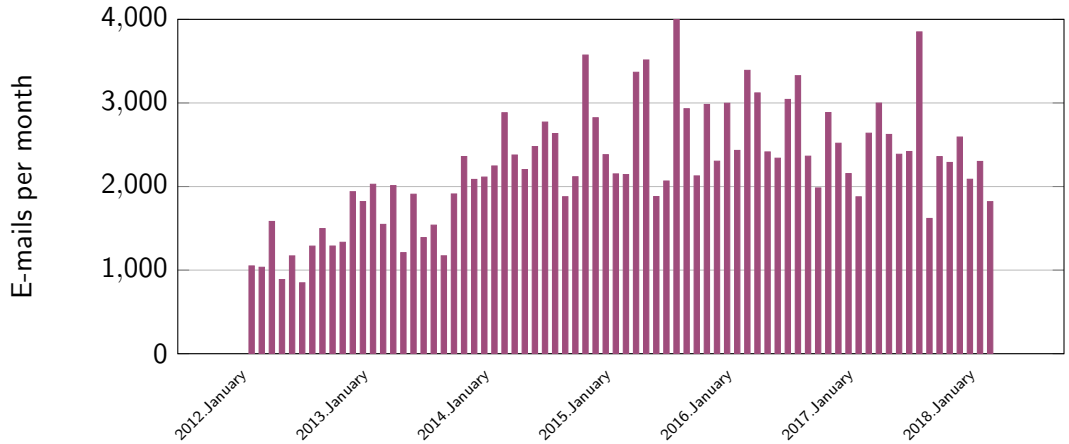
Project activity: contributors

Number of contributors per release



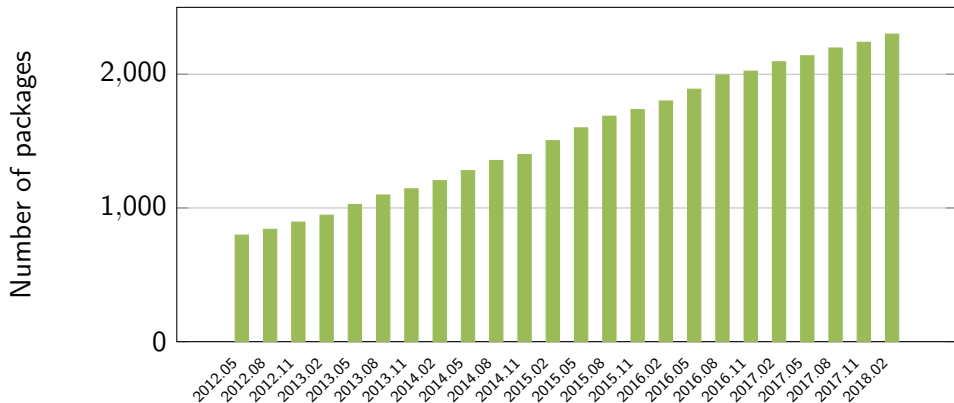


Project activity: mailing list activity





Project activity: packages





Release schedule and LTS

- ▶ Since 2009, releases every **three months**: YYYY.02, YYYY.05, YYYY.08, YYYY.11
 - ▶ Never skipped a release or missed a release date!



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 - ▶ Point releases for the latest stable, but only until the next stable release
 - ▶ Only option to get updates is to migrate to the next release
- ▶ Since 2017.02, one **LTS release** per year
 - ▶ Every YYYY.02 release will be **maintained for one year**, with security, build and bug fixes
 - ▶ 2017.02 had **10 point releases**, from 2017.02.1 to 2017.02.10, 778 commits
 - ▶ 2018.02 published on March 4th 2018, new LTS release



Maintenance and physical meetings

- ▶ Used to have a single committer/project maintainer: Peter Korsgaard
- ▶ **Two additional committers** have been appointed in recent years:
 - ▶ Thomas Petazzoni (i.e, me)
 - ▶ Arnout Vandecappelle
- ▶ **Physical meetings**
 - ▶ One meeting before ELCE,
 - ▶ One meeting after FOSDEM, Brussels
 - ▶ One more private hackaton for the core team in the summer





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 - ▶ ARC, ARM(eb,nommu), ARM64(eb), Blackfin, C-Sky, m68k, Microblaze(el), mips(64)(el), nios2, OpenRISC, PowerPC(64)(le), SuperH, Sparc(64), x86(_64), Xtensa



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- ▶ **ARM Cortex M3/M4 noMMU** support
- ▶ Merge of **ARM/ARM64** options, to select ARM64 cores
- ▶ **PowerPC64 little endian and big endian** support, contributions from IBM
- ▶ **MIPS improvements**: MIPS32r6 and MIPS64r6 support, MIPS core selection, NaN/FP32 selection, contributions from Imagination Technologies
- ▶ **OpenRISC, C-Sky, Sparc64** support
- ▶ Re-enabling of **m68k** both Coldfire (noMMU) and 68k (MMU)
- ▶ **Blackfin** and **Microblaze** improved with uClibc-ng support
- ▶ SH64 and AVR32 support removed



Toolchains

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- ▶ Internal toolchain improvements
 - ▶ Support for **musl** C library added
 - ▶ Moved from uClibc to **uClibc-ng**
 - ▶ **Regular updates**: gcc up to 7.x (default is 6.x), binutils 2.29 (default 2.28), gdb 8.0 (default 7.12), glibc 2.27, uClibc-ng 1.0.28, musl 1.1.19.
 - ▶ **LTO** and **Fortran** support
 - ▶ Toolchain **wrapper** also used for the internal back-end: allows sanity checks
 - ▶ eglibc removed



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 - ▶ **LTO** and **Fortran** support
 - ▶ Toolchain **wrapper** also used for the internal back-end: allows sanity checks
 - ▶ eglibc removed
- ▶ External toolchain improvements
 - ▶ Logic split in **multiple packages**, one per external toolchain family
 - ▶ Include/library paths **sanity checking** in the wrapper
 - ▶ Numerous **updates**: Linaro/Sourcery toolchains, new Imagination Technologies toolchains, removed old toolchains



- ▶ Side project, but Buildroot related
- ▶ Freely available **pre-built toolchains** for a wide range of architectures and configurations
- ▶ **34 different architecture/variants**
- ▶ glibc/uClibc-ng/musl, as available
- ▶ Two versions: stable and bleeding-edge
- ▶ Built by Buildroot, on Gitlab CI
- ▶ **Tested** by building a Linux kernel and minimal userspace, and if supported, booting under QEMU
- ▶ <https://toolchains.bootlin.com>


Download


Select arch

aarch64

Select libc

glibc


Download stable


Download bleeding-edge

✔ Tests passed

checksum (sha256)

| | |
|---------------|--------------------|
| binutils | 2.29.1 |
| gcc | 6.4.0 |
| gdb | 7.11.1 |
| glibc | glibc-2.26-144-... |
| linux-headers | 4.1.49 |

✔ Tests passed

checksum (sha256)

| | |
|---------------|------------|
| binutils | 2.29.1 |
| gcc | 7.3.0 |
| gdb | 8.0.1 |
| glibc | glibc-2.27 |
| linux-headers | 4.9.80 |

[View all aarch64 toolchains](#)



Infrastructure: relocatable SDK

- ▶ `output/host` contains
 - ▶ The native tools, including the cross-compiler
 - ▶ The toolchain `sysroot`, with all libraries and headers
- ▶ Can be used as an SDK
 - ▶ Allows application developers to build applications targeting the root filesystem without having to use Buildroot
- ▶ `output/host` is now **relocatable**, which makes it easier to use as an SDK
- ▶ `make sdk` prepares the SDK
 - ▶ Replaces absolute `RPATH` in native binaries by relative ones
 - ▶ Installs a `relocate-sdk.sh` script that users of the SDK must run to fix up the remaining absolute paths
- ▶ Related work:
 - ▶ `output/host/usr/*` moved to `output/host/`
 - ▶ `RPATH` in target binaries are now cleaned up



Infrastructure: hashes

- ▶ Each package now has a `<pkg>.hash` file that contains hashes
 - ▶ For the tarball being downloaded
 - ▶ For the patches being downloaded, if any
 - ▶ For the license files included in the upstream source code
- ▶ Tarball/patch hashes are checked when the package is extracted, i.e at every build
- ▶ License files hashes are checked when generating the licensing report
(`make legal-info`)
- ▶ Allows to:
 - ▶ check the integrity of what is downloaded,
 - ▶ ensure that tarballs stored locally have not been modified
 - ▶ detect if license terms have changed upstream
 - ▶ detect if upstream messes up and re-uploads a new (but different) tarball
- ▶ Almost all packages have a hash file now: 2247 packages out of 2315 packages

```
# Verified from http://ftp.isc.org/isc/bind9/9.11.1-P3/bind-9.11.1-P3.tar.gz.sha256.asc
sha256 52426e75432e46996dc90f24fca027805a341c38fbbb022b60dc9acd2677ccf4 bind-9.11.1-P3.tar.gz
sha256 d3906dfe153e2c48440d3ca1d5319f5e89b4b820cdfc5d0779c23d7ac2b175e9 COPYRIGHT
```



Infrastructure: licensing report

- ▶ Packages include a description of the license and paths to license files

```
DBUS_LICENSE = AFL-2.1 or GPL-2.0+ (library, tools), GPL-2.0+ (tools)
DBUS_LICENSE_FILES = COPYING
```

- ▶ Collected by `make legal-info`: source tarballs, patches, license files, manifests
- ▶ Improvements
 - ▶ **SPDX license codes** used to describe the licensing of all packages
 - ▶ **Hashes** added for license files, in order to detect changes
 - ▶ Storage of source code for binary artifacts such as pre-built toolchains, using `<pkg>_ACTUAL_SOURCE`
 - ▶ Many **more packages have license details**: 2223 out of 2315 packages



- ▶ BR2_EXTERNAL allows to implement packages, store *defconfigs* and other build-related files outside of the Buildroot tree
- ▶ Allows separating the upstream Buildroot from project/company-specific packages and data
- ▶ Simplified form of *layer* concept found in Yocto/OE/OpenWRT
- ▶ Available since 2014.02
- ▶ Improvements
 - ▶ Support for multiple BR2_EXTERNAL directories
 - ▶ Support for implementing bootloader packages and filesystem image formats in BR2_EXTERNAL



Infrastructure: package infrastructures

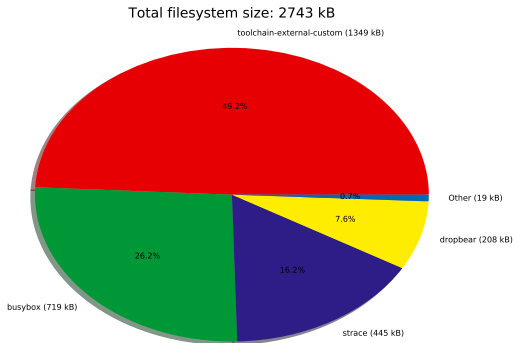
- ▶ Base infrastructure: `generic-package`
- ▶ Specialized infrastructures for specific build systems: `autotools-package`, `cmake-package`, `python-package`
- ▶ Improvements
 - ▶ `python-package` extended to support Python 3.x
 - ▶ New `perl-package` infrastructure for **Perl** packages
 - ▶ New `virtual-package` infrastructure for **virtual** packages such as OpenGL, jpeg, udev
 - ▶ New `waf-package` infrastructure for **Waf** based packages
 - ▶ New `rebar-package` infrastructure for **Erlang** packages
 - ▶ New `kconfig-package` infrastructure, used by Linux, BusyBox, uClibc-ng, Barebox, U-Boot, etc.
 - ▶ New `kernel-module` infrastructure to help building kernel modules



Infrastructure: graphing

- ▶ Already existing:
 - ▶ `make graph-depends`,
`make <pkg>-graph-depends`, to generate dependency graphs
 - ▶ `make graph-build`, graph of the build time per package
- ▶ Improvements
 - ▶ `make graph-size`, size of the filesystem, split by package
 - ▶ `make <pkg>-graph-rdepends`, graph of the reverse dependencies

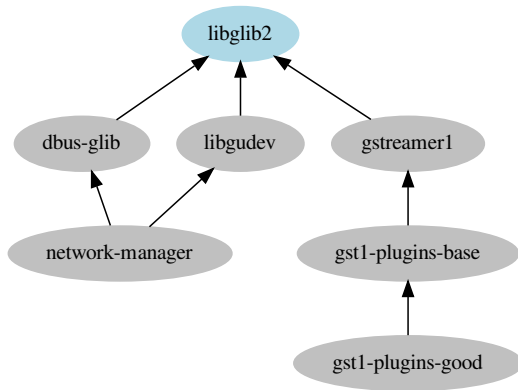
Filesystem size per package





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Infrastructure: *skeleton* restructuring

- ▶ **Skeleton:** base of the root filesystem, main directory hierarchy and basic config files
- ▶ Initially a single set of files copied to `TARGET_DIR` at the beginning of the build
- ▶ Now:
 - ▶ `skeleton` is a virtual package, that depends on `skeleton-init-sysv`, `skeleton-init-systemd`, `skeleton-init-none` or `skeleton-custom`
 - ▶ Common base: `skeleton-init-common`
 - ▶ Core init scripts moved in `initscripts`
 - ▶ Allows to avoid SysV cruft in systemd systems and vice-versa
 - ▶ Allowed to implement read-only rootfs support with `systemd`
 - ▶ Support for merged `/usr`, used by `systemd` support



Filesystem support

- ▶ Support for generating filesystem images in a large number of formats
- ▶ Improvements
 - ▶ `ext2`, `ext3` and `ext4` images now generated by `mkfs.ext<X>` instead of `genext2fs`, to better support `ext3/ext4`
 - ▶ Support for AXFS added
 - ▶ ISO9660 support re-written, to support Grub2 and Isolinux as bootloaders, `initramfs` and pure ISO9660 scenarios
 - ▶ Usage of `genimage` to generate complete SD card/MMC images in many *defconfigs*
 - ▶ Ability to specify a custom script to run within the *fakeroot* environment when creating filesystem images



Reproducible builds

- ▶ Idea: get binary identical results for repeated builds of a given configuration
- ▶ Option `BR2_REPRODUCIBLE` added
- ▶ Various things already fixed:
 - ▶ Sets `SOURCE_DATE_EPOCH`, used by gcc and various packages
 - ▶ Date/time of files in the filesystem
 - ▶ Build date, user, host name in the Linux kernel build and BusyBox
 - ▶ Remove timestamps in Python `.pyc` files
 - ▶ ...
- ▶ A lot more remains to be done. Unfortunately, the developers who started this work are no longer active.



Packages

- ▶ By far where most of the contributions go: updating existing packages and adding new packages
- ▶ More than **1000 packages** added between 2014.05 and 2018.02
- ▶ Significant updates/additions
 - ▶ SELinux support
 - ▶ Qt 5.9 (including Qt WebEngine), Gtk 3.x, EFL updates
 - ▶ OpenCV 3.0
 - ▶ Kodi
 - ▶ Go, Mono, Rust
 - ▶ Python modules (many!), Perl modules, Erlang modules
 - ▶ Docker, aufs
 - ▶ System upgrade: SWupdate, RAUC
 - ▶ HW support: AMD Catalyst, Freescale i.MX, NVidia, TI
 - ▶ Apache, ClamAV, Dovecot, MariaDB, Nginx, Asterisk
 - ▶ Glib C++ stack: glibmm, atkmm, cairomm, gtkmm, etc.
 - ▶ ... and SuperTuxKart!



Testing: runtime testing infrastructure

- ▶ Run-time test infrastructure added in `support/testing/`
- ▶ Test cases written in Python
- ▶ Build a given Buildroot configuration, boot under QEMU, run commands and check results
- ▶ Tests for filesystem images, packages, core functionality, init systems

```
class TestDropbear(infra.basetest.BRTest):
    config = infra.basetest.BASIC_TOOLCHAIN_CONFIG + \
        """
        BR2_SYSTEM_DHCP="eth0"
        BR2_PACKAGE_DROPBEAR=y
        BR2_TARGET_ROOTFS_CPIO=y
        # BR2_TARGET_ROOTFS_TAR is not set
        """

    def test_run(self):
        img = os.path.join(self.builddir, "images", "rootfs.cpio")
        self.emulator.boot(arch="armv5",
                           kernel="builtin",
                           options=["-initrd", img,
                                    "-net", "nic"])
        self.emulator.login("testpwd")
        cmd = "netstat -ltn 2>/dev/null | grep 0.0.0.0:22"
        _, exit_code = self.emulator.run(cmd)
        self.assertEqual(exit_code, 0)
```



Testing: CI

- ▶ Already existing:

<http://autobuild.buildroot.org>

- ▶ Set of 50 architecture/toolchain configurations
- ▶ Choose a random architecture/toolchain configuration, a random selection of packages, and build
- ▶ Results reported on a Web page, e-mailed to the mailing list

- ▶ Improvements

- ▶ All **defconfigs** are built on *Gitlab CI*
- ▶ **Run-time tests** are executed on *Gitlab CI*
- ▶ autobuild.b.o supports **testing multiples branches** (master, next, LTS)
- ▶ Notifications from autobuild.b.o sent to relevant developers

| | | | |
|--|-----------|--|---------------------|
| | #35289018 | tests.package.test_python.TestPython3 | 07:32 a week ago |
| | #35289019 | tests.toolchain.test_external.TestExternalToolchainBuildrootMusl | 03:39 a week ago |
| | #35289020 | tests.toolchain.test_external.TestExternalToolchainBuildrootuClibc | 03:16 a week ago |
| | #35289021 | tests.toolchain.test_external.TestExternalToolchainCCache | 05:17 a week ago |
| | #35289022 | tests.toolchain.test_external.TestExternalToolchainCngMusl | 02:55 a week ago |
| | #35289023 | tests.toolchain.test_external.TestExternalToolchainLinuxArm | 03:12 a week ago |
| | #35289024 | tests.toolchain.test_external.TestExternalToolchainSourceyArmv4 | 03:27 a week ago |
| | #35289026 | tests.toolchain.test_external.TestExternalToolchainSourceyArmv5 | 03:05 a week ago |
| | #35289027 | tests.toolchain.test_external.TestExternalToolchainSourceyArmv7 | 05:25 a week ago |
| | #35289048 | toradex_apalis_imx6_defconfig | 06:18 a week ago |
| | #35289049 | ts4800_defconfig | 04:48 a week ago |
| | #35289070 | ts4900_defconfig | 19:50 a week ago |
| | #35289071 | ts5x00_defconfig | 30:26 a week ago |



- ▶ `DEVELOPERS` file and associated `get-developers` tool
 - ▶ Much like `MAINTAINERS` in the Linux kernel
 - ▶ Used when sending patches
 - ▶ Used to report build failures per package or per-architecture to the relevant developers
- ▶ `check-package` script to detect obvious mistakes in packages
- ▶ `test-pkg` to build test a package with a large number of architecture/toolchain configurations
- ▶ `scanpypi` script to generate Python packages
 - ▶ Connects to *Pypi*, analyzes the metadata, and produces a Buildroot *package*

DEVELOPERS

```
N:      Waldemar Brodtkorb <wbx@openadk.org>
F:      arch/Config.in.bfin
F:      arch/Config.in.m68k
F:      arch/Config.in.or1k
F:      arch/Config.in.sparc
F:      package/glibc/
F:      package/mksh/
F:      package/uclibc/
F:      package/uclibc-ng-test/
```

test-pkg

```
armv5-ctng-linux-gnueabi [ 1/49]: OK
armv7-ctng-linux-gnueabihf [ 2/49]: OK
      br-aarch64-glibc [ 3/49]: OK
      br-arcle-hs38 [ 4/49]: SKIPPED
      br-arm-basic [ 5/49]: OK
      br-arm-cortex-a9-glibc [ 6/49]: OK
      .....

49 builds, 27 skipped,
0 build failed, 0 legal-info failed
```



Misc improvements

- ▶ **Linux extensions** infrastructure, to support building packages that need kernel patching: Xenomai, RTAI, specific drivers
- ▶ **Linux tools** infrastructure, to build user-space tools part of the kernel tree: *perf*, *gpio*, *iio*, *cpupower*, *tmon*, *self-tests*
- ▶ Complete revamp of the *gettext* handling, option `BR2_SYSTEM_ENABLE_NLS` to control native language support
- ▶ Checks on the architecture of cross-compiled binaries, to detect packages that do not cross-compile to the correct architecture
- ▶ Support for hardening features: *relro* and *fortify source*, still experimental.



Features on the radar

- ▶ Git download cache
 - ▶ Avoid re-cloning an entire Git repository every time the version/tag of a Git-fetched package is changed
- ▶ Per-package out of tree build
 - ▶ Avoids *rsync* when using *local* packages or `<pkg>_OVERRIDE_SRCDIR` and improves debugging experience
 - ▶ Avoids extracting the source code twice when building host and target variants
- ▶ Top-level parallel build
 - ▶ Building different packages in parallel
 - ▶ Requires per-package staging and host directories
- ▶ Improve package tooling
 - ▶ Track upstream package releases using <http://www.release-monitoring.org>
 - ▶ Track CVEs using the NIST database
- ▶ *Go* and *Meson* package infrastructures



Conclusion

- ▶ Active project
- ▶ LTS releases with security updates
- ▶ Relocatable SDK
- ▶ Rich and up-to-date package set
- ▶ Good and increasing testing effort
- ▶ Interesting new features on the roadmap

Getting started with Buildroot tutorial at this ELC as part of the E-ALE track, on Wednesday at 2:30 PM.

Questions? Suggestions? Comments?

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<https://bootlin.com/pub/conferences/2018/elc/petazzoni-buildroot-whats-new>

Support our crowdfunding campaign to develop
an upstream Linux kernel driver for Allwinner VPU

<https://bootlin.com/blog/allwinner-vpu-crowdfunding/>

